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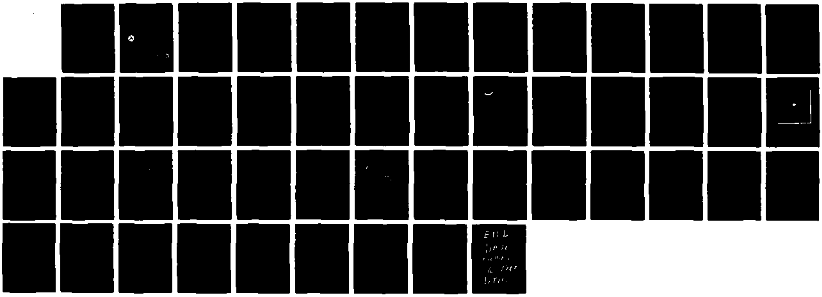

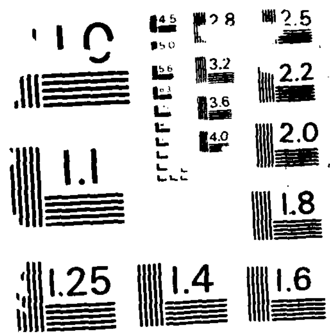

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Report No. CG-D-02-88

DESCRIPTIONS OF HF AND VHF LORAN-C BUOYS AND EVALUATIONS AS POTENTIAL DATUM MARKER BUOYS

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This report is the twenty-second in a series which documents the Improvement in Probability of Detection in Search and Rescue (POD/SAR) Project at the U.S. Coast Guard Research and Development Center.

16. Abstract

The U.S. Coast Guard Research and Development Center has tested two types of Loran-C drifting buoys as prototypes for replacements for the presently used Radio Direction Finder (RDF) type Datum Marker Buoys (DMB). The buoys used HF or VHF transmission of the buoy's Loran-C Time Differences to a shore/ship based receiver at 10 to 100 minute intervals. Field testing of the buoys at sea occurred off Cape Cod, MA; Cape May, NJ; and Georges Bank, MA.

Of the two types of buoys the one using VHF technology proved to be more suitable for future development than that using HF technology. The main reasons for the better results with the VHF versus HF buoys was simplicity and reliability. Results indicated that the VHF buoys can survive severe weather, transmit data reliably, and have sufficient range for useful tracking and data collection. Tests indicated reliable data reception at 20 nautical miles (nm) from a vessel and 50-60 nm from an airborne receiver.

The advantage of the Loran-C buoys over the RDF DMB is the increased data collection rate and that the data collection does not interrupt the ongoing search. The Loran-C buoys are being incorporated into a system to be used to establish a working search datum and for defining the sea surface currents of the search area in real-time.

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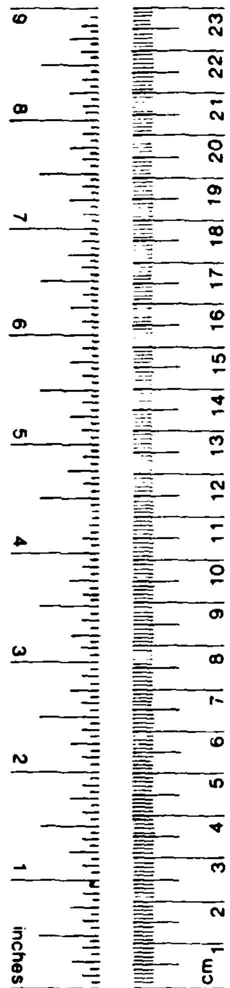
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price \$2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

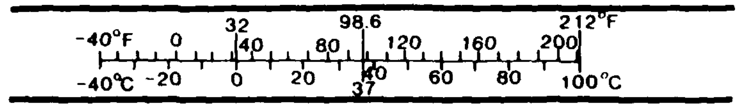


TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ACKNOWLEDGMENTS

The authors would like to express their appreciation for the many hours of work by Dr. Ronald Schlitz and Jack Green of NMFS/NOAA Woods Hole, MA, Bill Whalen of Ocean Communication Systems Inc., Dr. Paul Greisman and Mark Hill of Dobrocky-Seatech, and to Mr. Mike Couturier, LCDR Robert Vorthman, and Dr. David Paskausky of the U.S. Coast Guard Research and Development Center.

The support of the crew and scientific party of R/V Albatross IV for their support during Nauset Light and Georges Bank field tests is greatly appreciated.

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CHAPTER 1

INTRODUCTION

1.1 Background

The Search and Rescue problem that search planners deal with is composed of elements which range from the reporting of the incident through the planning and execution phases into the post incident review and critique, Figure 1-1. The initial twin considerations when dealing with the "search" part of the Search and Rescue problem are firstly how best to search an area, and secondly what area to search. In this paper information and conclusions are presented on the equipment tests that have application to the second part of the "search" problem.

It has often been stated that no matter how thorough the search or how sophisticated the search platform, the Probability of Detection (POD) of the search object is nil if the search object is not within the planned search area. Search areas are set around what is referred to as "search datum" or just "datum" (the most probable location of the search object). Initially, datum must be established in some manner. This may range from a distress call giving an exact location to a datum based on indirect or circumstantial information as in the case of an overdue boat. After datum is established initially, the fact that it may move must then be addressed. Datum will be moved by both the search object's leeway (caused by direct wind force acting on the search object) and search object's drift (caused by the action of sea surface currents, tides, and waves). The focus of this paper is the movement of datum by the sea currents and the prediction, measurement, and analysis of this movement.

The movement of datum by currents and tides has usually been handled by resorting to archived current information compiled from numerous sources and presented as averages. These averages typically cover large periods of time, decades at least. Also, these averages cover large areas of ocean, usually on a three or

SEARCH AND RESCUE PROBLEM DEFINITION

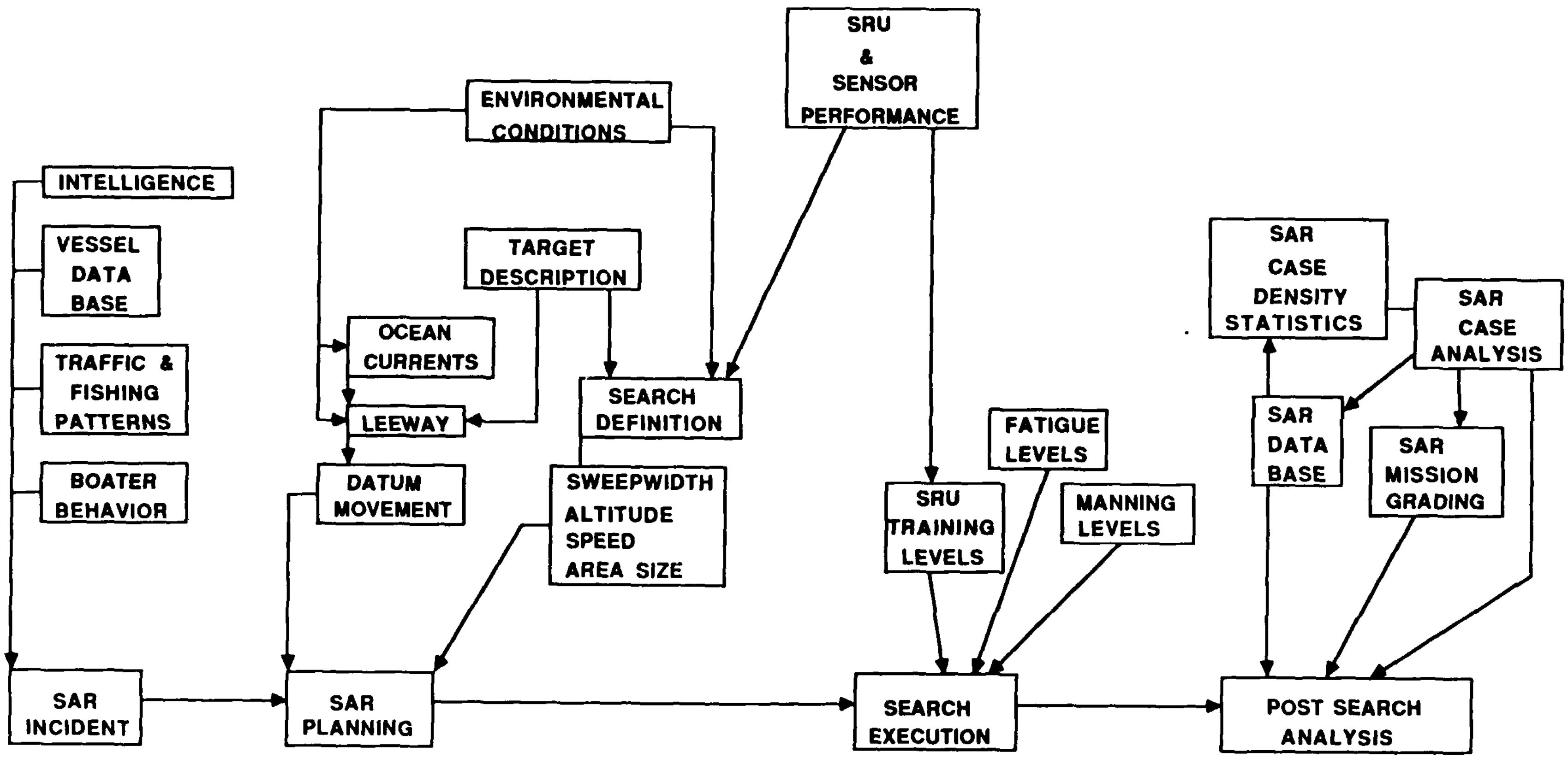

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FIGURE 1-1 THE SEARCH AND RESCUE PROBLEM DEFINITION five degree grid of latitude and longitude. More recently, current charts have been prepared from numerical models operated by the US Navy Fleet Numerical Oceanographic Center. The model results are more timely, but tend to suffer from the lack of "ground truth" and the very coarse grid used. In Murphy, et al. (1982) and Murphy and Allen (1985) comparisons were made between actual drifts of search datum and drift projected by current models and archived averages. These comparisons indicated that for fewer than 10% of the drift trials, projections of the movement of datum, after 24 hours, resulted in search areas which included the search datum in <u>any</u> part of the projected search areas.

The alternative to using historical or model currents is to measure the actual currents in the vicinity of datum during the search. A family of devices has been used for the purpose of marking a parcel of water being searched. These devices range from a block of wood or a life jacket to a manufactured Radio Direction Finder (RDF) transmitting buoy called a Datum Marker Buoy (DMB). DMB's are currently used in searches by Coast Guard aircraft. The technique for measuring the currents with these devices is to locate them initially and then relocate them when information on the movement of the datum is desired. In the case of the RDF DMB the aircraft can either take several bearings on the buoy in quick succession or actually fly over the buoy by homing in on the signal. A disadvantage that immediately becomes apparent is that locating this type of DMB disrupts an ongoing search with a secondary search for the DMB. If the DMB is relocated, then this technique results in very few current measurements since the current is computed by dividing the drift displacement by the time between locating events.

A buoy which transmits a signal containing the buoy's unique identity and its location would have great advantages over the RDF type DMB. Current technology offers a number of possible choices in this area of buoy design. The three which we have examined are buoys which can be located by satellite using Service ARGOS, by satellite using Global Positioning System (GPS) and by shore-based receivers using Loran-C. Since Service ARGOS is not a real-time system and the GPS is not yet mature we have chosen to work with a prototype DMB utilizing Loran-C and a capability to transmit the Loran-C time-differences (TD's) to shore, ship, or aircraft.

Loran-C buoys will provide the surface current information without diverting a search unit to find the DMB. To use the search resources more efficiently, the buoys' drift information must be part of a search planning system. This drift information system should quickly, easily, and inexpensively gather reliable real-time information on the sea surface currents, deliver the data to be automatically analyzed, and then presented in a useful manner to the search planners for the projected drift of datum. The mere accrual of data is not enough; information for decision making is the desired goal.

1.2 Report Overview

The Oceanography Branch of the R&D Center as part of the POD/SAR project has investigated the potential of two types of Loran-C buoys to replace the presently used RDF type DMBs. Eight buoys, two HF and six VHF buoys, were purchased and tested in the field. The buoys were to provide oceanographic surface current information and to develop the working knowledge necessary to replace the RDF DMBs and to start design of the drift information system. Both types of buoys have the same basic design and are freely-drifting surface buoys. An onboard Loran-C receiver and antenna receives the Loran-C signals at preselected intervals and then transmits the buoy ID, time, and Loran-C data to the base receiver. The receiver then outputs the data in ASCII to either a printer or a computer.

The basic buoy design problem is the same for both buoy types. The output power should be maximized while the power consumed should be minimized. This increases the range and number of data transmissions while decreasing the on board battery power supply requirement. Two fundamentally different design approaches were taken by the buoy manufacturers. Ocean Communication Systems, Inc. (OCSI), Panama City, Florida, uses a sophisticated transmitter and antenna to transmit at an HF frequency (4.16 MHz). Dobrocky-Seatech, Sidney, British Columbia, uses off-the-shelf equipment to transmit at a VHF frequency (30.46 MHz).

The HF OCSI and the VHF Dobrocky-Seatech buoys are described along with the field tests. Evaluations, conclusions and recommendations are made at the end of this report.

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CHAPTER 2
HF LORAN-C BUOYS

2.1 Buoy Description

Two freely-drifting prototype A-6 buoys fabricated by Ocean Communications Systems, Inc. (OCSI), Panama City, FL, 32405 (904-769-0122), were purchased for measuring ocean currents. The buoys, shown in Figure 2-1, consist of a nine foot long PVC pipe with a watertight instrument box and flotation attached at midpoint. The PVC pipe is four inches in diameter and closed at both ends. The lower portion of the pipe contains six Yuasa NP 2.6 AH - 12 V batteries which act as partial ballast. Additional ballast and a drogue are attached to the bottom of the buoy. The upper portion contains the Loran-C receiving antenna and the HF transmitting antenna. The instrument box contains a Si-Tex 787C Loran-C receiver, controller board, encoder board and transmitter. The Loran-C time delays, buoy ID, and time are encoded aboard the buoy and then transmitted via HF, at 4.160 MHz to the shore or ship based antenna and receiver. The sea-surface is used as a ground plane for the surface wave propagation. The data is encoded for transmission in an error correction scheme to prevent data loss to noise. The transmission is a phase-coherent, phase shift-keyed modulation scheme. This is the same scheme used by NASA for their telemetry of data from space back to earth. The shore antenna is a dual-loop active antenna. It uses a pair of preamps driven by 12 VDC from the OCSI PRD-2 receiver. The receiver detects the coherent phase modulated signal and then decodes the signal. The data is outputted via a RS-232 port to either a printer or a computer. This is a sophisticated system of highly tuned antennas and encoded data. It uses the sea surface as the transmission plane to send a weak signal in a high noise environment to a very sensitive receiver system. The clear advantage of this system is a potential for transmitting data over great distances (greater than 100 nm) with very low power consumption.

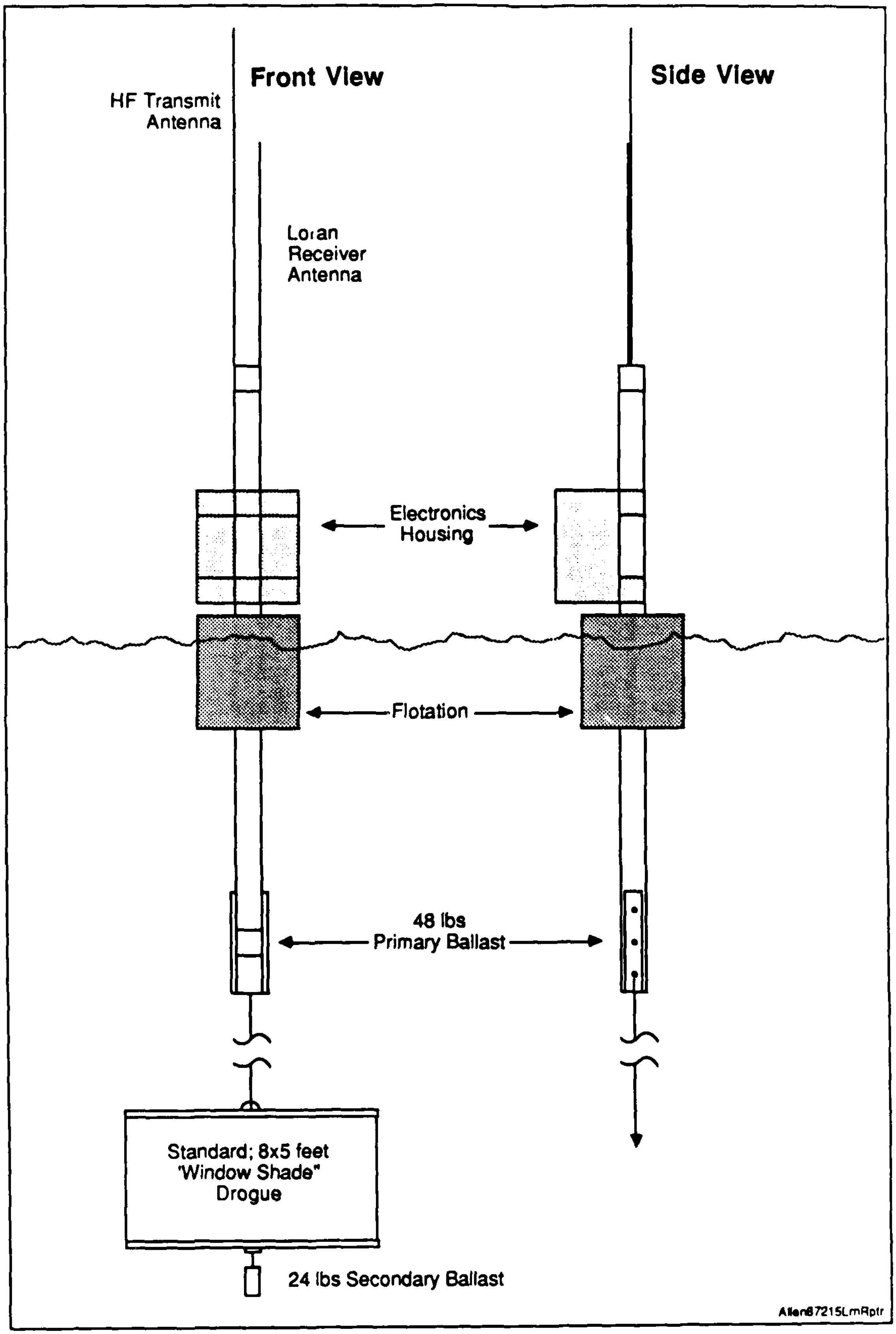

FIGURE 2-1. THE HF LORAN-C BUOY BUILT BY OCEAN COMMUNICATION SYSTEMS, INC.

2.2 Field Tests

Two A-6 HF buoys (USCG #648, #649) were ordered from OCSI in May 1983 and delivered in March 1985 to the R&DC. Delays in delivery were mainly due to problems and changes with the Loran-C receiver used in the buoys. At the same time, two identical buoys (NMFS #646, #647) were delivered to the Northeast Fisheries Center, NMFS/NOAA, Woods Hole, MA. Several local field tests and three major open-ocean field tests have been conducted on these buoys in cooperation with Ronald Schlitz and Jack Field of NMFS, and Bill Whalen of OCSI.

2.2.1 Nauset Light, July 1985

The first field tests of the HF buoys were off Cape Cod in July 1985. The buoys were delivered to the Northeast Fisheries Center, Woods Hole, MA, on 2 July 1985 and checked out with the NMFS receiver. A problem was corrected with the USCG buoys at that time when tested with the NMFS receiver. The Research Vessel Albatross IV left Woods Hole with both the USCG and NMFS buoys on 3 July and headed for the Great South Channel area. The OCSI PDR-2 receiver and ICOM HF transceiver were set up in the Nauset Lighthouse, Eastham, Cape Cod. The ICOM HF transceiver provided communications between the Nauset Light and the R/V Albatross IV. The USCG buoys transmitted at 4.162 MHz at 150 baud. The NMFS buoys were set to transmit at 4.194 MHz at 300 baud. The PRD-2 receiver at Nauset Lighthouse had a fixed crystal tuned to the USCG buoys. Aboard the R/V Albatross IV there was an ICOM HF tunable receiver with an OCSI decoder and RS-232 port attached. The USCG buoys were lashed to the rails on the aft of the R/V Albatross IV. From the evening of 5 July until the afternoon of the 8 July we attempted to listen to the USCG buoys. The ship steamed in a zig-zag pattern northeastward towards the center of Georges Bank. Typically the ship was 80 to 100 nm from Nauset Light. The buoys transmitted data which was received aboard the ship with the NMFS's ICOM receiver, but was not received at

Nauset Light with the PRD-2 receiver. Apparently, there was too much loss due to the ship's hull acting as part of the antenna and therefore greatly detuning the antenna.

Several modifications were made to the test procedure as a result of this field experiment before the November 1985 field test. First, the buoys were tested in the water, not on deck, which eliminated the detuning problem caused by the ship's hull. Secondly, the USCG purchased an active antenna to replace the passive wire antenna. This provided the best possible reception. Thirdly, the NMFS buoys were changed to the USCG's buoys' frequency. Fourthly, the USCG buoys were changed to 300 baud. These changes made NMFS and USCG buoys compatible with the PRD-2 receiver which was also changed to 300 baud. The ICOM HF transceiver provided excellent communications with the ship.

2.2.2 Nauset Light, November 1985

The second field test took place just off Cape Cod, 22-25 November 1985. The PRD-2 receiver with the dual-loop active antenna and an ICOM HF transceiver was set up at the Nauset Lighthouse. A Ray-53 VHF transceiver was used for communications with the ship. Both the USCG and NMFS buoys were taken aboard the R/V Albatross IV. In the evening of 23 November, NMFS buoy #647 was deployed 3 nm off Nauset Light and was kept tethered to the ship. The PRD-2 receiver managed to receive and decode one transmission from the buoy. All further attempts to receive the transmission of buoy #647 by the PRD-2 failed. After this failure the ICOM HF transceiver was tuned to the buoy's frequency. While this didn't allow decoding the data, the signal had a distinct auditory pattern which allowed estimates of signal strength to be made. During 24 November, NMFS buoy #646 was set up on deck of the R/V Albatross IV. USCG buoy #649 did not maintain a charge on the batteries and therefore was not tested further. Buoy #647 was untethered from R/V Albatross IV which then steamed south maintaining good reception for up to 23 nm. The signal was lost at 25-26 nm by the ICOM receiver aboard the R/V Albatross IV. At 2100 hours on 24 November buoys #647 (NMFS) and #648 (USCG) were deployed 3 nm off Nauset Light and the R/V Albatross IV steamed north. The R/V Albatross IV's ICOM receiver was still receiving both buoys when they turned around at 40.5 nm. Since the directional antenna faces fore and aft with obstructions forward, the best signal reception was when the buoy lay astern.

Several more modifications were made after this test. The entire operating system in the buoys was changed to provide clearer and simpler instructions, which made the buoys much easier to work with. Bill Whelan of OCSI came to the R&DC to tune the buoys, antenna, and the PRD-2 receiver. He also developed an instrument for tuning the transmitting antenna on the buoys. With all the batteries fully charged and the bad battery on buoy #649 replaced, all four buoys were then retuned. Thus they were ready for the November 1986 test.

2.2.3 Georges Bank, November 1986

A third test of the buoys was conducted in cooperation with NMFS in November 1986 aboard the R/V Albatross IV. The test of the HF buoys was aborted when the PRD-2 receiver aboard the ship failed to decode the signals from the buoys on deck. The ICOM HF receiver with decoder and RS-232 output had been returned to OCSI. Since there was not a backup receiver, we turned our attentions elsewhere.

The two USCG buoys and associated equipment have been permanently transferred to the NMFS for their use and maintenance. The search for an effective DMB has been switched from a dual HF/VHF approach to one which will pursue only the VHF option.

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CHAPTER 3

VHF LORAN-C BUOYS

3.1 Buoy Description

Buoy specification for six VHF Loran-C buoys were drawn up in February 1985 at the R&D Center. Solicitations were made in April 1985. The contract was awarded to Dobrocky-Seatech, Sidney British Columbia in June 1985. The contract was modified in August 1985 to provide memory onboard the buoys for the storage of buoy positions, and selectability of Loran-C chains. Five buoys (#'s 11,12,13,15,16) were delivered to the R&D Center in April 1986. A sixth buoy (#14) was kept at Dobrocky-Seatech for further testing and evaluation.

The bodies of the five Dobrocky-Seatech drifting buoys consist of ellipsoid fiberglass hulls designed to minimize wind drag yet provide a stable platform. The hull has a diameter of 112 cm and is 60 cm in height (Figure 3-1). The hull is made of two halves bolted together, with a neoprene gasket providing a watertight seal. Internally 6.0 and 7.5 volt alkaline batteries provide power and ballast. The electronics system consists of an Internav 310 Loran-C receiver, a controller-timer-encoding circuit and a 75 watt Standard Communications Corporation, Model 966L VHF/FM Low Band transmitter operating on a frequency of 30.46 MHz. Sampling and transmission interval can be preselected from 10 to 100 minutes. Each transmission is repeated once per second for 1 to 10 seconds. The transmitted signal consists of a buoy identification number, time, and buoy position as Loran-C Time Differences (TDs). The buoys are equipped with non-volatile data storage memory. This memory is used to save the transmitted time differences in the event the transmissions are not picked up by the receiver. The data may be recovered from the memory upon recovery of the buoy. The receiver system is from Meteor Communications Corporation. The MCC 985 Data Communications Receiver, with a FSK to RS-232 decoder has two ports; one for a printer and another for computer data display and logging. The

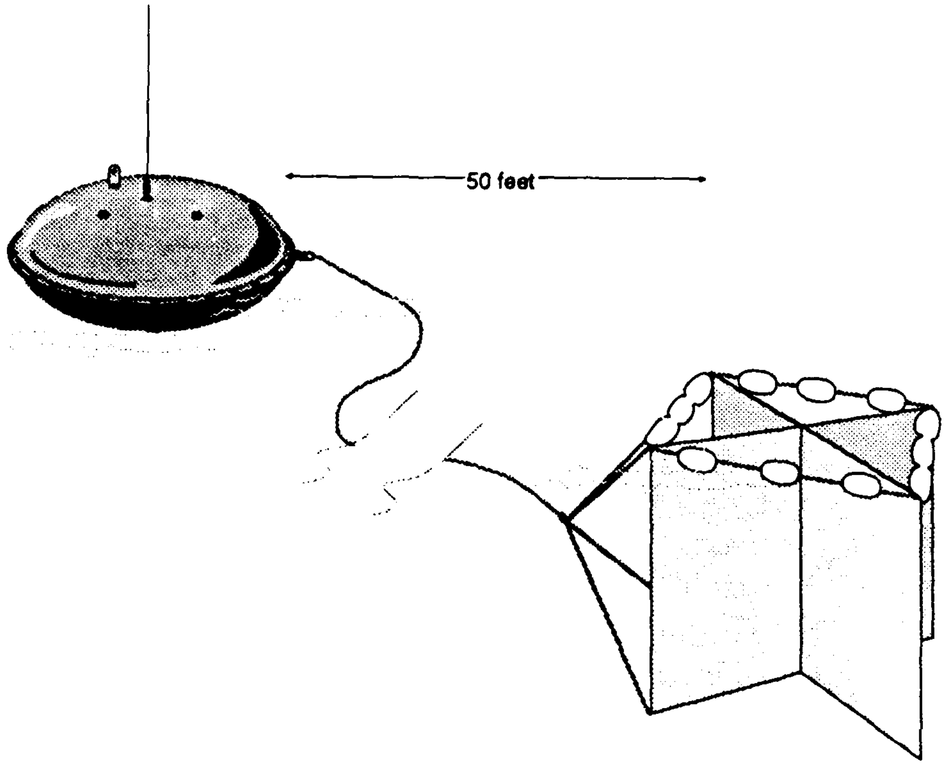


FIGURE 3-1. THE VHF LORAN-C BUOY BUILT BY DOBROCKY-SEATECH AND THE DROGUE BUILT BY THE R&D CENTER FOR THE VHF LORAN-C BUOYS.

receiving antenna is constructed of three pieces, a seven foot fiber-glass whip and two eight foot anodized aluminum pipes for a total of 23 feet. Proper mounting of the antenna is critical to the reception range of the buoys.

The drogues were designed and manufactured at the R&D Center. They are two 2m (long) by 1.5m (deep) crossed fabric panels. Aluminum poles top and bottom hold the nylon panels in place. Wire and bunge cord sections were connected to the ends of the poles to maintain the drogues in an "X" configuration. Ten small fishing floats provided just enough buoyancy to float the top of the drogue at the water surface. A four point bridle connecting both the top and bottom provides the attachment point for the line from the buoy. The heavier gage aluminum poles on the bottom and the hardware of the bridle provide sufficient ballast for the drogue. The use of a four point bridle prevents kiting of the drogue when a force is applied along the tether line. During the recovery of buoy #13 on 3 May by the USCG Cutter Point Franklin the drogue acted as a sea anchor and nearly held the USCGC Pt. Franklin in place. This indicates that these buoys with drogues do track the surface waters.

3.2 Field Tests

Two major field tests and one minor field test have been conducted with the VHF Loran-C buoys. Three separate deployments were made off Cape May, NJ, during the April-May 1986 POD/SAR field experiment for Visual Distress Signalling Devices. In November 1986, in cooperation with NMFS, Woods Hole, MA, five buoys were deployed and recovered by the Albatross in the Great South Channel area between Georges Bank and Nantucket Shoals. On 15 January 1987 the data receiver was tested aboard an HH3F helicopter from the Coast Guard Air Station (CGAS) Cape Cod.

3.2.1 Cape May, NJ, April-May 1986

The Oceanography Branch of the R&D Center in cooperation with Coast Guard Group Cape May conducted a four week field experiment for the POD/SAR project. The principal experiment was to test the effect of Visual Distress Signalling Devices on the POD of surface and aircraft searches during the day and night. During this time three separate deployments of the VHF Loran-C buoys were also made.

A receiving station was established at Townsends Inlet, NJ. The receiving antenna was mounted on the rail of the third story deck of a beach house 150 yards back from the water's edge. Line of sight was unobstructed between 50° and 170° True which encompassed all of the study area. Data was logged onto disk by a HP 200 series computer and also printed on hard copy. The Loran-C TDs of the buoys were plotted during the deployments by hand on Nautical Chart 12318 to produce buoy tracks. Standard weather information was collected at Air Station Cape May and at Station Atlantic City at 3 hour intervals.

A preliminary float test and three separate deployments of the buoys was conducted during the course of the field experiment. The first deployment was one buoy for 50 hours. The second deployment was two buoys for four days and the third deployment was of three buoys for two and a half days.

On 14 April a preliminary float and stability test of buoy #11 was conducted. The undrogued buoy was deployed 8 nm offshore of Townsends Inlet near the Avalon Shoal Buoy over the side of the utility boat (UTB) CG-42048. The water line on the buoy was just below the lip between the two halves of the hull. Several passes by the UTB near the buoy were made to observe the effect of the UTB's wake on the buoy. The buoy remained upright and stable. Upon trying to turn the buoy over by hand, it was turned to about 100 degrees before it righted itself. This gave confidence that the buoy will remain upright in heavy seas. During a later deployment the buoys remained upright in 3-5 ft seas. However, the buoy did rock enough to set up large whipping motions in the antenna that would dip the tip of the antenna into the water causing signal loss. The presence of the drogue system didn't seem to lessen the problem. During a night deployment one buoy entered the water on its side and turned upside down. These buoys are not self-righting and are stable in the up-side down position. It was easily righted upon returning to the buoy. The suggestion of using a spar type buoy for the next generation has been passed on to Dobrocky-Seatech.

A single point check on the accuracy of the positions from the buoy was made. At 17:25 on 14 April 1986 we had the buoy on board the UTB CG-42048 and we were as close as possible to the Avalon Shoal Buoy. The Avalon Shoal buoy was positioned by the CGC Hornbeam with Loran-C. The position given by the CGC Hornbeam was 39 05'23"N, 74 33'58"W. The 1982 chart 12318 position is 39 05'40"N, 74 34'00"W. The CGC Hornbeam makes Loran-C corrections at the pier and then sets the buoy at the ideal Loran-C TDs, with a watch circle radius of 51 yards. The TDs from the Loran-C buoy were 27011.78 and 42847.98, which plots at 39 05'46"N, 74 33'55"W on 1982 chart 12318. This quick check indicates that the buoys are giving positions accurate to several hundred meters. The repeatability of Loran-C TDs is well known, Wenzel and Slagle (1983). Figure 3-2 reproduced here from Wenzel and Slagle (1983) is the 95% probability contours of the radial distance of the root-mean-square Loran-C error for the East Coast. At Cape May, New Jersey the error is less than 40 meters. The April-May 1985 radial root-mean-square error of the X and Y TD's from the Loran-C monitoring site at Lewes, Delaware is shown in Figure 3-3. The year-to-year variation is small compared to the seasonal variation (Slagle, personnel communication), so this is a good representation of the repeatability of the Loran-C signals during April-May 1986 for Cape May New Jersey. During the field test, the ability to recover the buoys in fog based on the most recent TDs transmitted

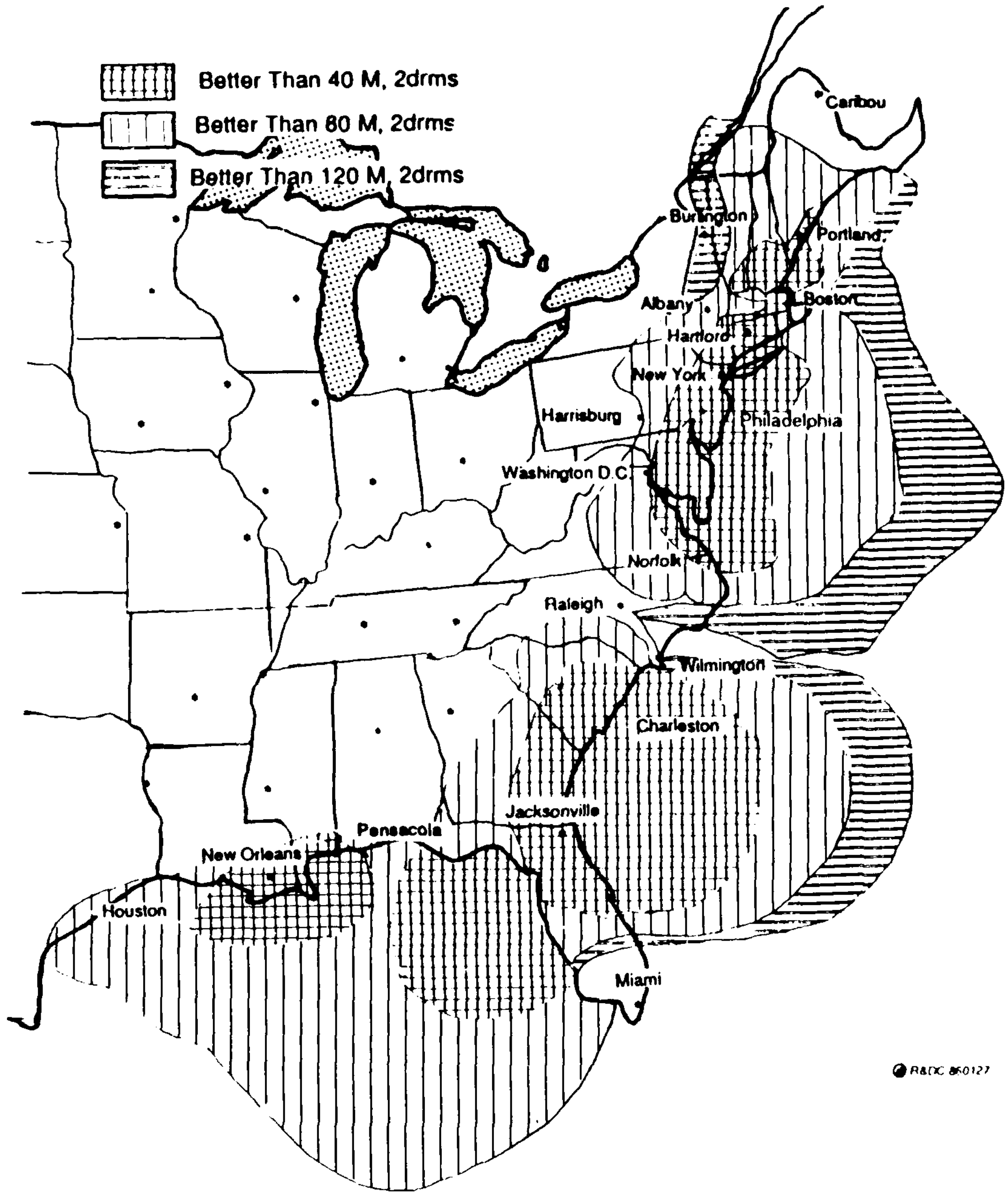


FIGURE 3-2 THE 95% PROBABILITY CONTOURS OF THE RADIAL DISTANCE ROOT-MEAN-SQUARE ERROR FOR THE EAST COAST, FROM WENZEL AND SLAGLE (1983).

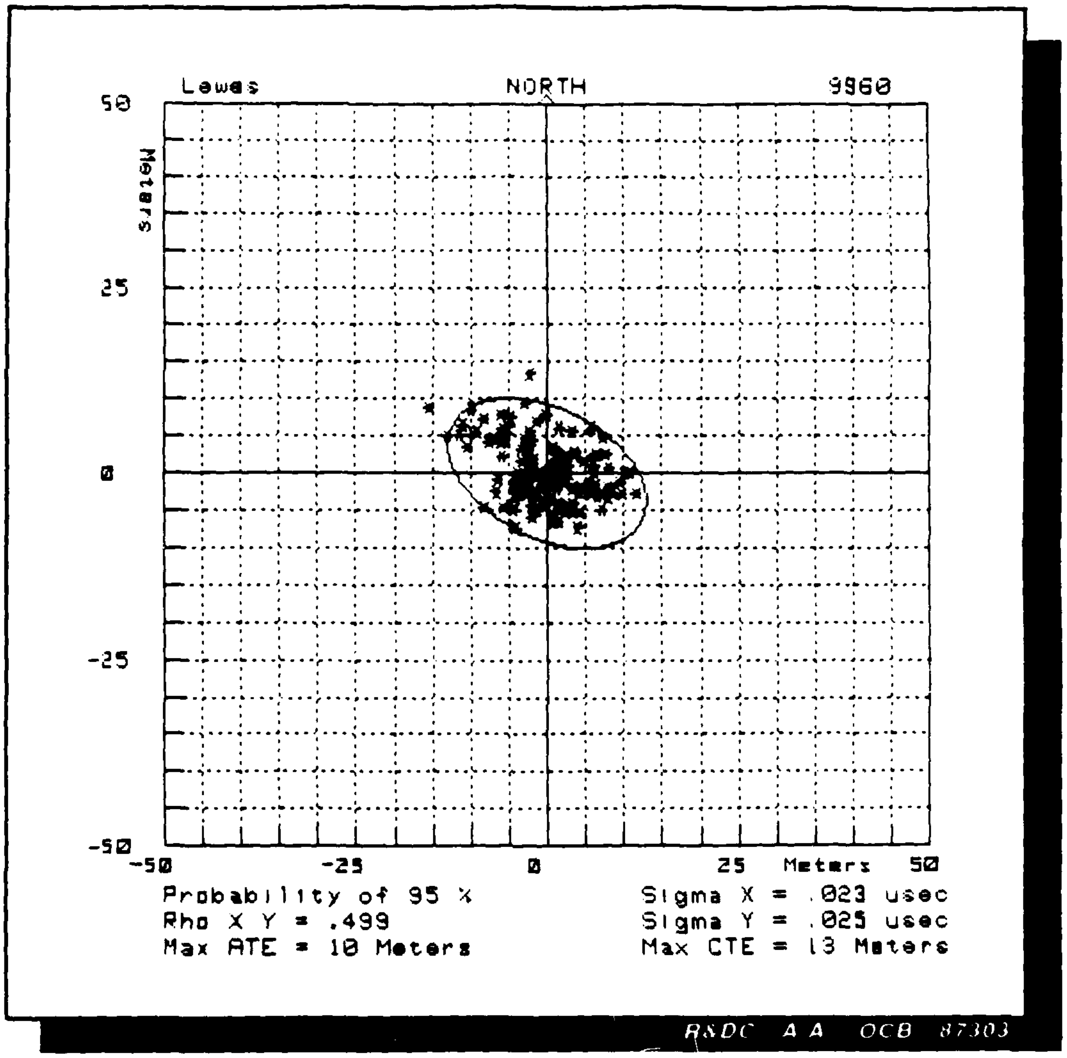


FIGURE 3-3 RADIAL ROOT-MEAN-SQUARE ERROR OF THE LORAN-C SIGNAL FOR APRIL-MAY 1985 FROM THE HARBOUR MONITOR SITE AT LEWES, DELAWARE.

by the buoys also demonstrated the resolution of Loran-C at several ten's of meters.

The first deployment in the freely drifting mode of buoy #11 was on 21 April 1986 at 1238 hours two miles north of the Avalon Shoal Buoy. The buoy track shown in Figure 3-4 has crosses for each ten minute transmission time. The initial time (00:00) was at 12:00:00 EST. There was a 10 minute interval between transmissions. The buoy was drogued at the surface. The buoy drifted 4 nm northwest in eight hours and then made small (less than 1 nm) loops for 24 hours. The buoy headed south for 20 hours covering 12 nm before it was recovered 12 nm off Hereford Inlet. This was 15 nm from our Townsends Inlet receiving station.

The second deployment was on 29 April 1986. Two buoys, #13 and #16 were successfully deployed at 4 and 12 nm off Great Egg Inlet (Ocean City). Buoy transmission intervals were set to 30 minutes. The tracks of the buoys #13 and #16 are shown in Figure 3-5. Two more buoys were scheduled for deployment off Absecon Inlet (Atlantic City). The second buoy was not launched off Absecon Inlet, since the first buoy was unable to transmit successfully the 21 nm to our receiver in Townsends Inlet. The weather was calm with patchy fog. We were able to reconstruct the TDs from the Absecon Inlet buoy and then recover it despite the dense fog. We received transmissions from the Great Egg buoys, 15 - 18 nm from the Townsends Inlet receiver.

The Great Egg inshore buoy #13 made several open clockwise loops of 3 to 7 nm diameter first to the east and then to the south. The offshore buoy #16 made similar open loops. Both buoys were recovered when north winds were driving them southward. At 1434 hours on 1 May buoy #16 and its drogue were picked up by the

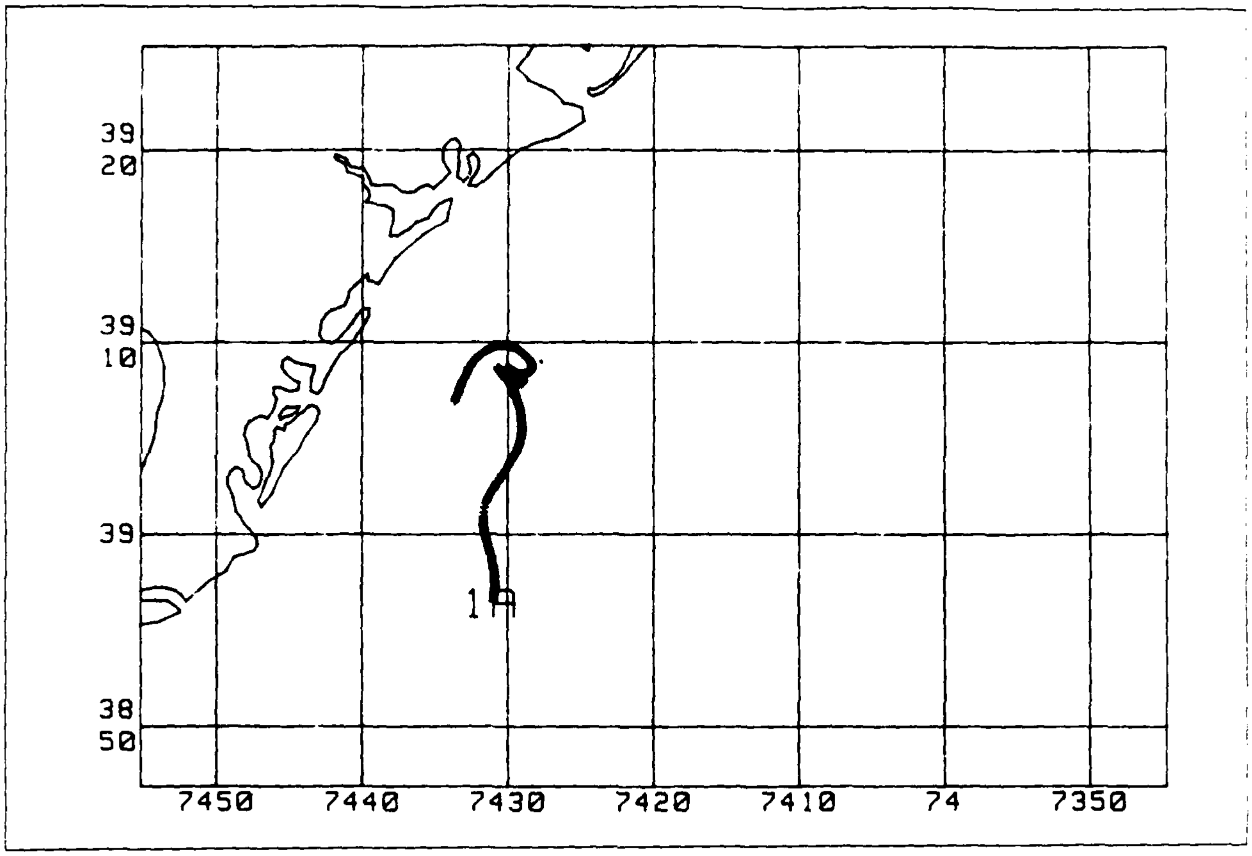


FIGURE 3-4 CAPE MAY, NJ, FIELD TEST, FIRST DEPLOYMENT. BUOY #11 DEPLOYED AT 17:50 Z ON 21 APRIL 1986, RECOVERED AT (1A) 18:00 Z 23 APRIL 1986. CROSSES ARE AT EACH 10 MINUTE SAMPLING INTERVAL.

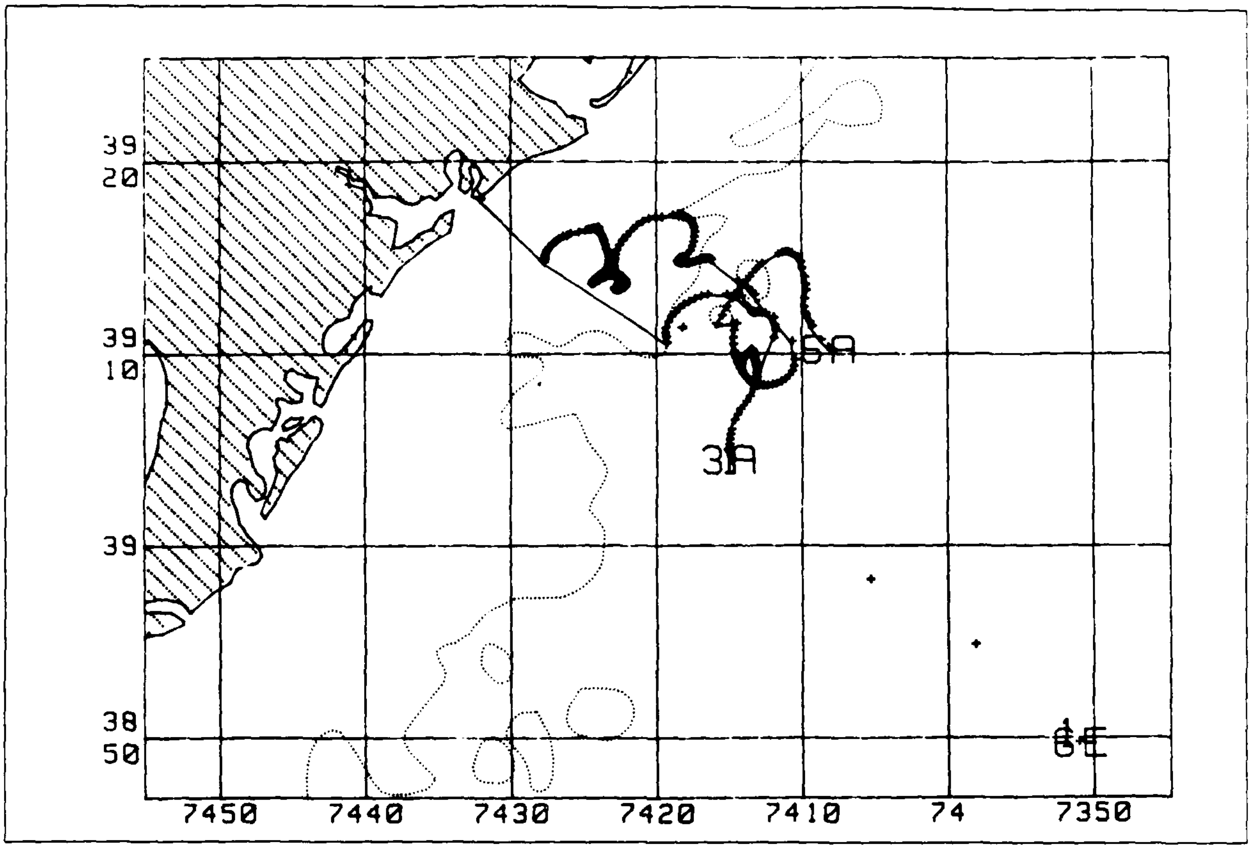


FIGURE 3-5 CAPE MAY, NJ, FIELD TEST, SECOND DEPLOYMENT. BUOY #13 WAS DEPLOYED AT 13:58Z ON 29 APRIL 1986 AND RECOVERED AT (3A) 12:58Z 3 MAY 1986. BUOY #16 DEPLOYED AT 14:29Z 29 APRIL 1986 AND LAST DATA COLLECTED BY THE SHORE WAS RECEIVED AT (6A) 13:29Z 2 MAY 1986; POSITIONS WERE LATER RECEIVED BY THE USCGC POINT FRANKLIN FROM 17:29Z TO RECOVERY AT (6E) 15:29Z ON 3 MAY 1986. CROSSES ARE AT EACH 30-MINUTE SAMPLING INTERVAL.

fishing vessel Mt. Vernon. The drogue was destroyed, and the buoy minus the drogue was reset by the Mt. Vernon one mile to the west of where they recovered it. The track of the undrogued buoy was not sufficiently different from the track of the drogued buoy to indicate that the drogue had been lost. The data will be investigated further to determine if there are subtle differences between drogued and undrogued buoy drifts.

The third deployment was just after midnight on 6 May 1986. The buoys were deployed in a triangular pattern 5.5 to 6.5 nm on a side. The tracks are shown in Figure 3-6 . Buoy #16 was launched 4 nm off Corson Inlet. Buoy #11 was launched at 10.5 nm off Corson Inlet. Buoy #12 was deployed 7nm off Townsends Inlet. All three buoys were recovered with the drogues attached and in good condition. Buoys #16 and #11 had similar tracks over the two and half day deployment. Both moved northeastward along the coast for 24 hours, and then looped offshore to move southwestward along the coast again. Several loops or partial loops were made on the southwestward portion of the drift. The offshore buoy, #11, had a greater longshore excursion than the inshore buoy, #16. Winds at Atlantic City were out of the southwest at 10-15 knots during 6 May and then shifted to the northeast at about 5 knots during the rest of this period. The southern buoy, #12, moved eastward offshore for the first 24 hours, and then moved southward in a "S" shaped pattern. The general picture that is suggested is of a southwestward longshore current during this time, with variation in that current, and a strong wind driven component when the winds exceeded 10 knots. Tidal influences were nil.

The tests established these buoys as reliable working buoys. A great deal of information was gathered by the buoys, as evidenced by the nearly complete buoy tracks. The working range for a shore or ship based receiver was established at about 20 to

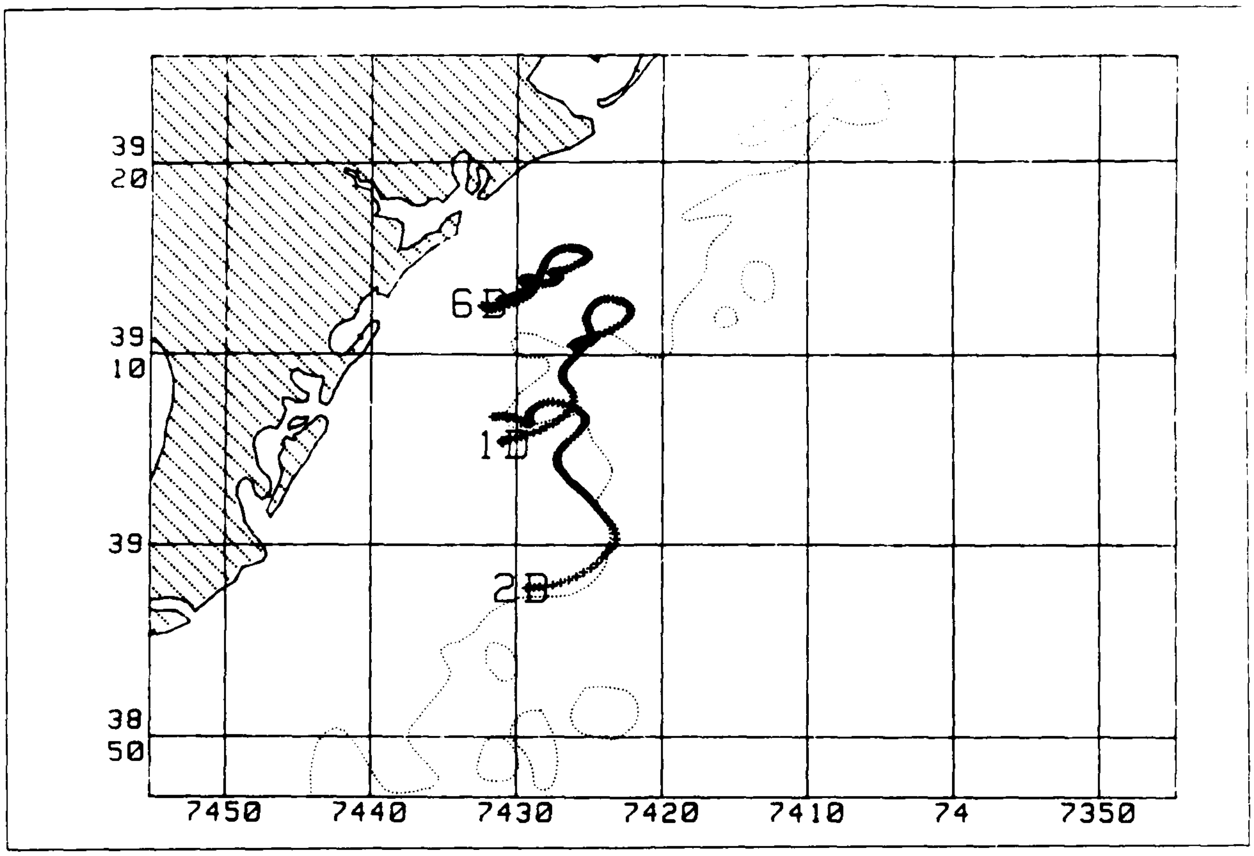


FIGURE 3-6 CAPE MAY, NJ, FIELD TEST, THIRD DEPLOYMENT. BUOY #11 WAS DEPLOYED AT 4:01Z 6 MAY 1986 AND RECOVERED AT (1D) 8:01Z 8 MAY 1986. BUOY #12 WAS DEPLOYED AT 11:59Z 6 MAY 1986 AND RECOVERED AT (2B) 13:59Z 8 MAY 1986. BUOY #16 WAS DEPLOYED AT 3:30Z 6 MAY 1986 AND RECOVERED AT (6B) 15:30Z 8 MAY 1986. CROSSES ARE AT EACH 30-MINUTE SAMPLING INTERVAL.

25 nm. Buoys #13 and #15 started to show problems with the Loran-C receiver onboard jumping 10 micro-seconds due to the receiver choosing the wrong zero cross of the Loran-C signal. The memory on board the buoys did not work during the experiment. The EPROM was later modified by Dobrocky-Seatech before our November 1986 test, during which the on-board memory did work.

3.2.2 Georges Banks, November 1986

In cooperation with NMFS/NOAA, Sandra Eynon and Arthur Allen of the R&D Center participated in R/V Albatross IV cruise 86-06. This cruise's main purpose was to recover three current meter moorings in Great South Channel. There was additional time to conduct a hydrographic survey, and to deploy and recover the USCG VHF Loran-C buoys. The 22 foot antenna was set up on the starboard rail of the third deck with a connection down to the receiver on the second deck. Prior to the cruise the necessary software was developed by Mike Couturier and LCDR R. Vorthman to transfer the data from the MCC data receiver directly into the GAADS system on a HP 300 series computer. The GAADS system is a real-time Geographic, Analysis, Archiving and Display system, Vorthman (1986). The figures displaying the buoy tracks from both the Cape May and Georges Bank field tests are from the GAADS system. The HP 236 with a hard disc and floppy disc drive was used with GAADS to store and display the buoy tracks.

Buoy #11 remained on deck with its power on. This provided a cruise track of the R/V Albatross IV. During the first half of the cruise (Figure 3-7) the boat steamed out to the test area through Nantucket Sound. The legs of the hydrographic survey and the cluster of positions around each mooring recovery can be clearly seen. The buoy was recording positions every half hour. Two short deployments of #11 were made, but the buoy was quickly recovered when it was discovered that the range of the transmission was less than 3 nm. The reason for the reduced range is presently under investigation.

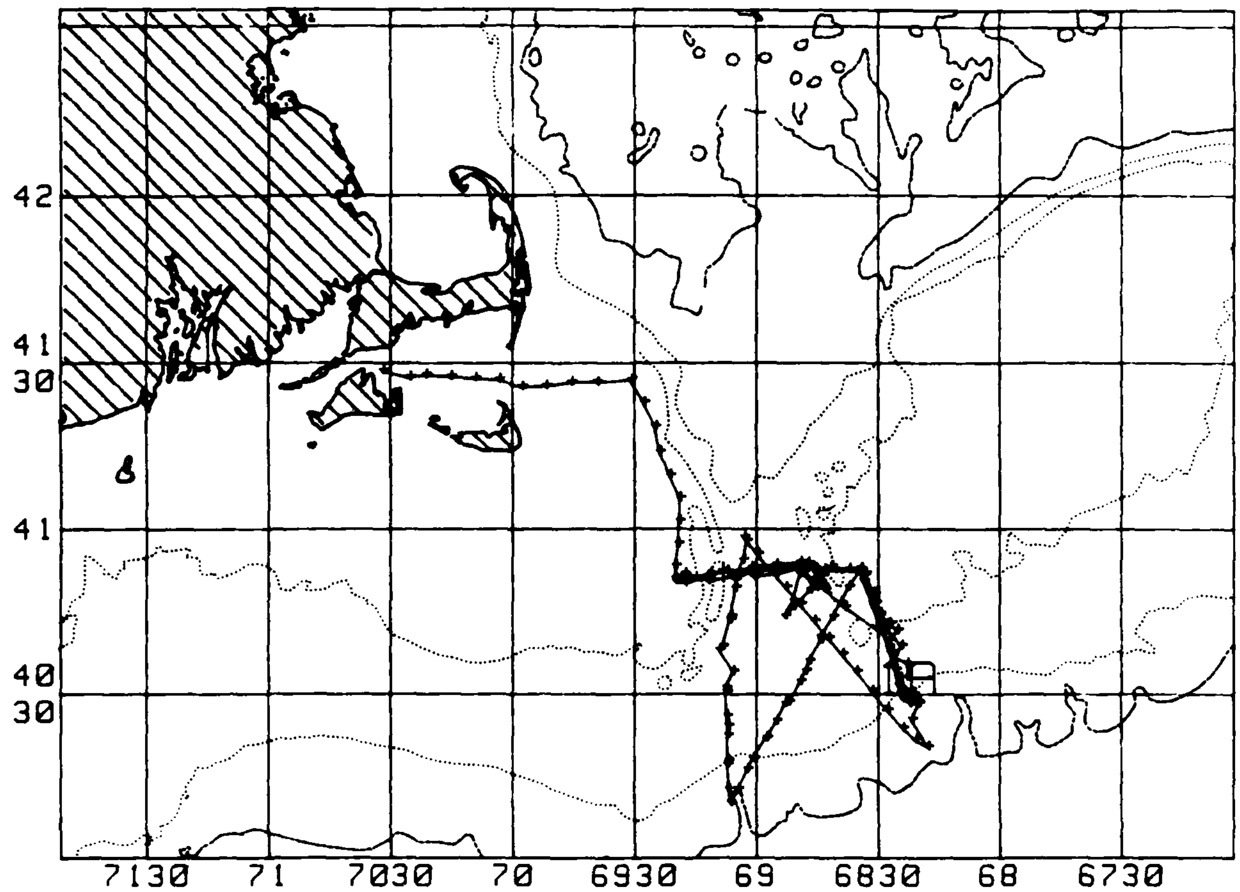


FIGURE 3-7 GEORGES BANK FIELD TEST, CRUISE TRACK. BUOY #11 ABOARD R/V ALBATROSS IV FROM 14:58Z 14 NOVEMBER 1986 TO (1A) 5:28 18 NOVEMBER 1986. CROSSES ARE AT EACH 30-MINUTE SAMPLING INTERVAL.

Buoys #15 and #16 were deployed on 16 November 1986 on either side of a NMFS/NOAA current meter mooring. This will provide a six hour comparison between the buoy velocities and the currents measured by a Vector Measuring Current Meter at 5 meters depth. Buoy #15 was recovered after one and half tidal cycles on 17 November. Buoy #15 was then redeployed along with buoys #12 and #13 in a north-south line. Two tidal cycles later, these three buoys were recovered on 18 November just before a storm. Buoy #16 remained in the water until after the storm on 19 November. The buoy tracks from the stored edited data are shown in Figure 3-8.

Upon returning to the R&D Center the positions stored in each buoy were dumped to a floppy disc. Using the GAADS system, plots were generated from the data. There were two basic types of data. The first type is raw-transmitted data from the buoys to the receiver aboard the ship which represents the real-time data available to the user, Figure 3-9. The second type is raw-stored data from the buoy's memory which will include all of the raw-transmitted data plus the data lost in transmission, Figure 3-10. This data set was processed into edited-stored data which is the best possible representation of the buoy tracks, Figure 3-8. This procedure was used on the Cape May data with the editing taking place on the raw-transmitted data, since there was no stored data. Thus for Cape May we have raw-transmitted and edited-transmitted data sets.

One of the advantages of deploying several buoys at one time, from a development perspective, is that a variety of problems will arise in the different buoys. Buoy #11, as mentioned, had a transmission power problem limiting the range to less than 3 nm. Buoys #13 and #15 continued to have 10 microsecond jumps in the Loran-C signal. Buoy #12 had a loose antenna. The loose antenna led eventually to the buoy being unable to settle at all on the Loran-C signal. Buoy #16, experiencing none of these problems, rode out the storm of 19

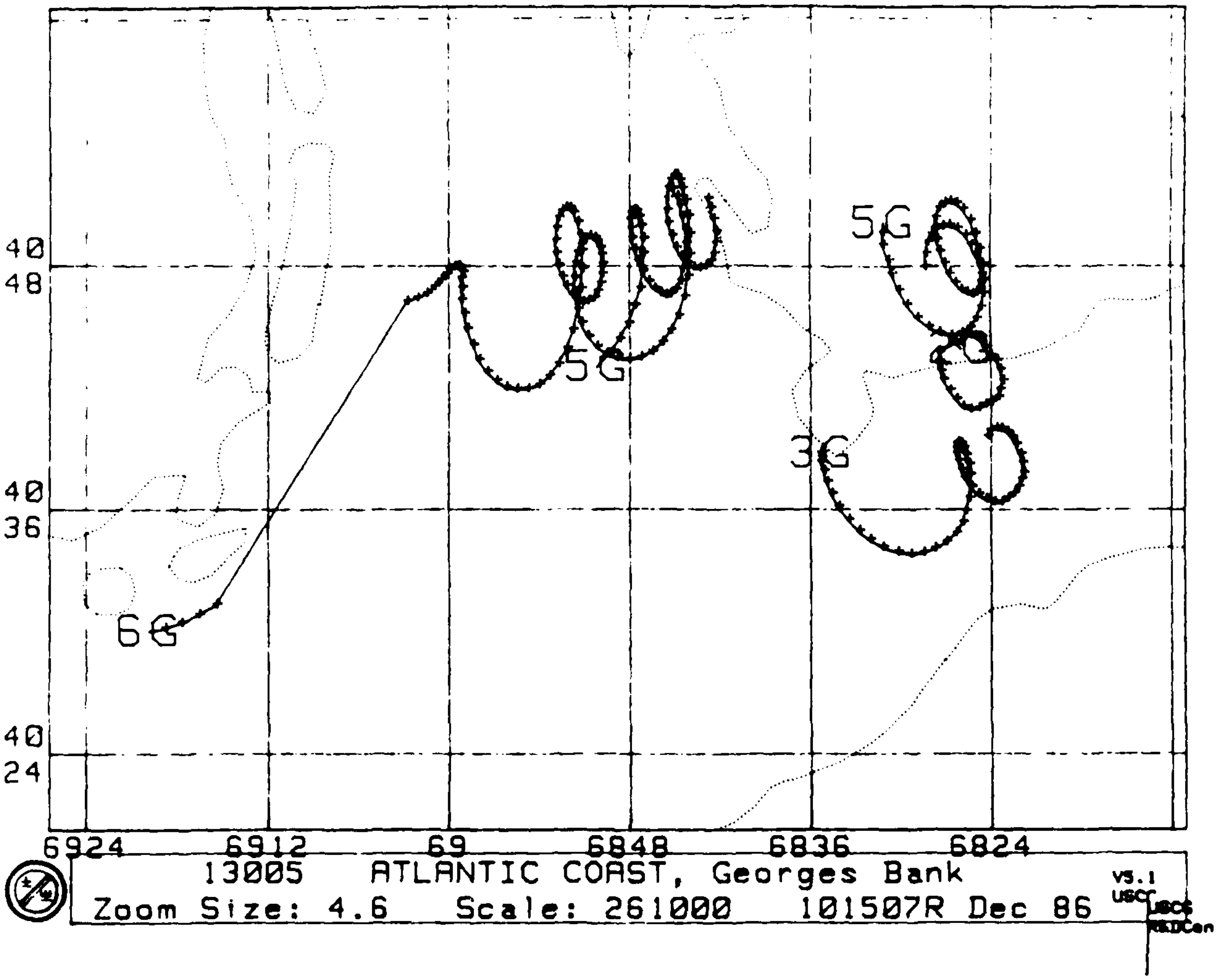


FIGURE 3-8 GEORGES BANK FIELD TEST, BUOY TRACKS, EDITED - STORED DATA. BUOY #16 WAS DEPLOYED AT 6:30Z 17 NOVEMBER 1986 AND RECOVERED AT (6G) 2:00Z 20 NOVEMBER 1986. BUOY #15 WAS DEPLOYED 5:29Z 17 NOVEMBER 1986 AND RECOVERED AT (5G - 43°43.0'N, 68°50.2'W) 22:29Z 17 NOVEMBER 1986 AND REDEPLOYED AT 2:59Z 18 NOVEMBER 1986 AND RECOVERED AT (5G - 40°50.1N, 68°31.1W) 4:29Z 19 NOVEMBER 1986. BUOY #13 WAS DEPLOYED AT 4:32Z 18 NOVEMBER 1986 AND RECOVERED AT (3G) 6:32Z 19 NOVEMBER 1986. BUOY #12 WAS DEPLOYED AT 4:31Z 18 NOVEMBER 1986 AND RECOVERED AT (2G) 18:01Z 18 NOVEMBER 1986. CROSSES ARE AT EACH 30-MINUTE SAMPLING INTERVAL.

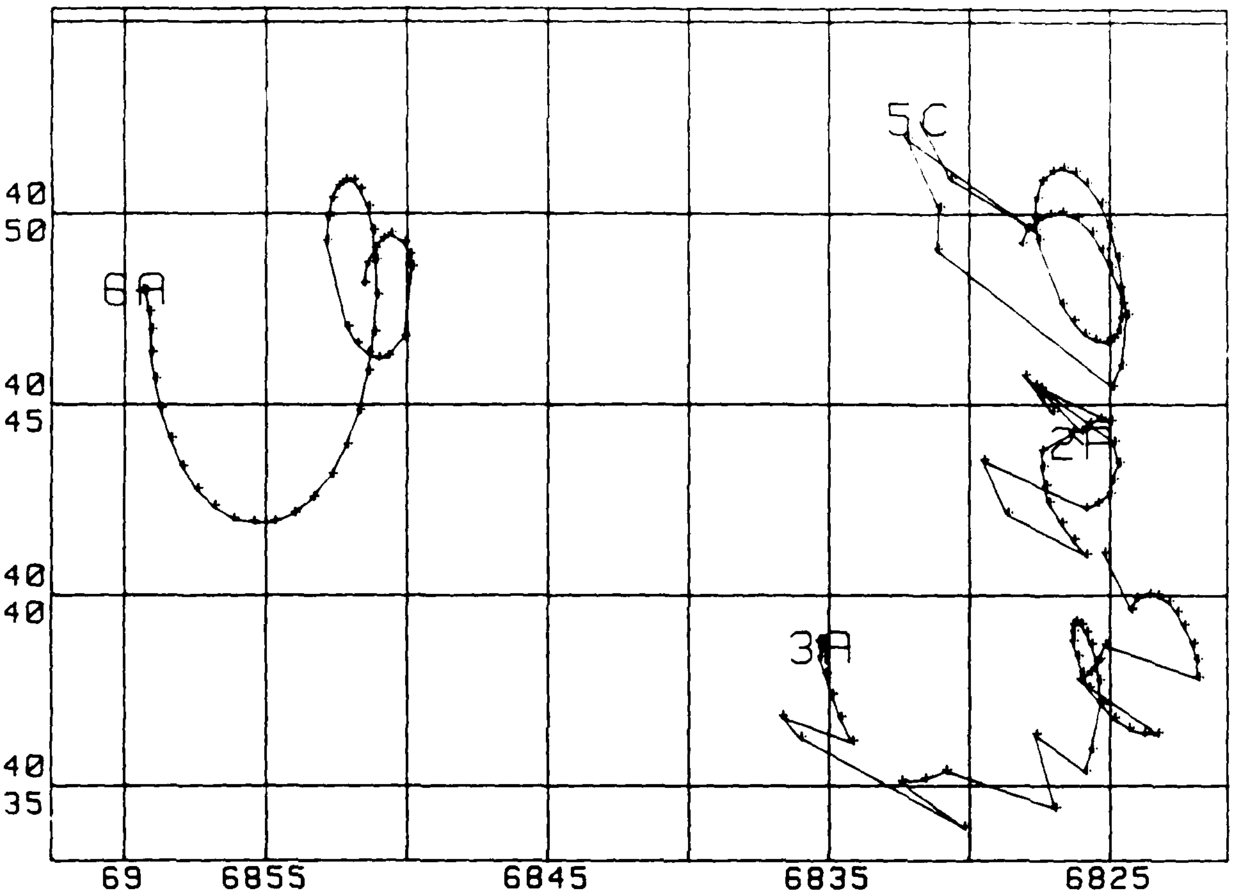


FIGURE 3-9 GEORGES BANK FIELD TEST, BUOY TRACKS, RAW - TRANSMITTED DATA. BUOY #16 WAS DEPLOYED AT 6:30Z 17 NOVEMBER 1986 AND ENDED AT (6A) 1:30Z 18 NOVEMBER 1986. BUOY #15 WAS DEPLOYED AT 2:59Z 18 NOVEMBER 1986 AND RECOVERED AT (5C) 4:29Z 19 NOVEMBER 1986. BUOY #13 WAS DEPLOYED AT 4:32Z 18 NOVEMBER 1986 AND RECOVERED AT (3A) 6:32Z 19 NOVEMBER 1986. BUOY #12 WAS DEPLOYED AT 4:31Z 18 NOVEMBER 1986 AND RECOVERED AT (2A) 18:01Z 18 NOVEMBER 1986. CROSSES ARE AT EACH 30-MINUTE SAMPLING INTERVAL.

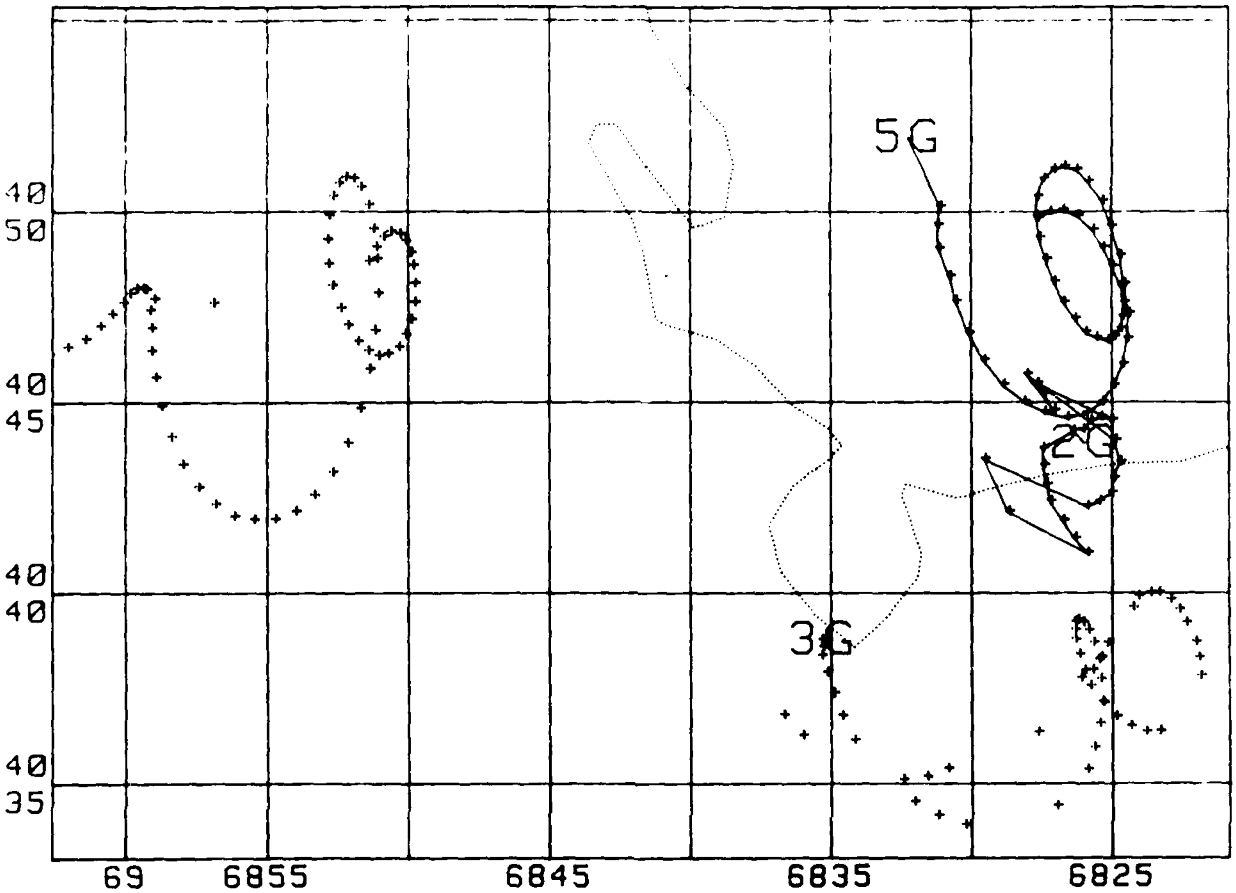


FIGURE 3-10 GEORGES BANK FIELD TEST, BUOY TRACKS, RAW - STORED DATA. BUOY #16 WAS DEPLOYED AT 6:30Z 17 NOVEMBER 1986 AND RECOVERED AT (6G - NOT SHOWN ON THE FIGURE) 2:00Z 20 NOVEMBER 1986. THE TRACK OF #16 IS UNCONNECTED CROSSES ON WESTERN SIDE OF FIGURE. BUOY #15 WAS DEPLOYED AT 2:59Z 18 NOVEMBER 1986 AND RECOVERED AT (5G) - 4:29Z 19 NOVEMBER 1986. BUOY #13 WAS DEPLOYED AT 4:32Z 18 NOVEMBER 1986 AND RECOVERED AT (3G) 6:32Z 19 NOVEMBER 1986. THE TRACK OF BUOY #13 IS THE UNCONNECTED CROSSES ON THE EASTERN SIDE OF THE FIGURE. BUOY #12 WAS DEPLOYED AT 4:31Z 18 NOVEMBER 1986 AND RECOVERED AT (2G) 18:01Z 18 NOVEMBER 1986. CROSSES ARE AT EACH 30-MINUTE SAMPLING INTERVAL.

November. When the winds exceeded 45 knots during the storm the onboard raw-stored data showed the Loran-C receiver was unable to settle on the Loran-C signals. When the winds reduced to 30-35 knots the buoy was again able to settle on the Loran-C signal, even though the seas were still running at the same 15 feet height that they were at the height of the storm. Thus it appears that it is the short steep waves that rock the buoy that interfere with the Loran-C reception and not being hidden in trough of the swells. The transmission of data followed the same pattern as the Loran-C reception. The onboard storage of the data permitted us to sort out the receiver/transmitter source of data loss. The range of successful transmission remained at about 25 nm from the buoys to the ship. However, a sector of transmission was blocked by the ship's superstructure. This was only a problem when the buoys were near maximum range from the ship.

Deployments were made by lowering the buoys over the rail with a crane using a quick release hook. A premature release during the test of one buoy allowed the buoy to drop 15 feet with no ill effects. Recovery proved easy. We took advantage of the flasher during night recovery, but basically used the last position transmitted to steer an intercept course. The flasher made visual contact at about a half mile very easy, even when the winds were increasing to 30-40 knots. Recovery was accomplished by snagging the line between the drogue and the buoy with a hook, recovering the drogue first, and then recovering the buoy. The importance of recovering the drogue prior to the buoy was established.

3.3.3 CGAS Cape Cod, January 1987

On 15 January 1987 a static transmission test of the buoys was conducted to determine (a) whether the MCC data receiver would operate on the 115 VAC, 400 Hz power of CG aircraft, (b) whether the receiver could be hooked up to existing aircraft antenna, (c) which antenna provided the best signal, and (d) at what range could the buoys be received. To conduct this test, technical assistance and an HH3F helicopter was provided from CGAS Cape Cod. Buoy #15 was placed at the light house at Avery Point, Groton, CT and buoy #16 was place near the runway at Air Station Cape Cod. Both buoys were on 10-minute intervals beginning at four and five minutes past the hour. A ground test of the receiver indicated that both the H3's VHF and HF antennas would receive the buoy's signal and that the antenna connections inside the aircraft were accessible.

While airborne the reception range on both the HF and VHF antennas was tested. The receiver has three basic responses: (a) receive the signal and decode the data (a "within range" response), (b) receive the signal and be unable to decode it (an "at range" response), and (c) not be able to receive the signal (a "greater than range" response). The HF antenna proved to be superior to the VHF antenna. The VHF antenna was "at range" at 16.5 nm and an altitude of 3000 feet. Therefore the HF antenna was used during the rest of the tests. The HF antenna is a long-wire antenna running along the port side of the HH3F from the tail to the wheel strut to the nose. At the 1000 foot flight level the buoys were received by the HF antenna in the following manner: (a) at 54 nm a "within range" response, (b) at 64 nm an "at range" response, and (c) at 71 nm a "greater than range" response. At 3000 feet the buoys were received by the H3's HF antenna at 60 nm as "within range", and were "at range" at 77 nm. The results are summarized in Table 1.

TABLE 1

RECEIVED RANGE OF THE DOBROCKY-SEATECH VHF LORAN-C BUOY USING THE HH3F HIGH FREQUENCY (HF) ANTENNA

	Within Range (nm)	At Range (nm)	Greater Than Range (nm)	Horizon Range (nm)
1000 ft	54	64	71	36.2
3000 ft	60	77	Not tested	62.7

CHAPTER 4

EVALUATION OF TESTED BUOYS AS POTENTIAL DATUM MARKER BUOYS

4.1 HF Loran-C Buoys - OCSI

The HF Loran-C buoys from OCSI produced limited data and then only briefly. This occurred during 24 November 1985 test from the R/V Albatross IV when the ICOM receiver on board was able to receive signals from two buoys up to 23nm and 40nm. Every other attempt to get the whole system to work resulted in the discovery of a new and often fatal flaw in the system. Some of the problems encountered were: The transmitter aboard the buoys had to be tuned while the buoys were in the sea without land, docks, boats or bodies nearby to cause interference, usually a difficult task. The placement of the dual loop antenna near the water's edge was critical to reception to avoid signal losses over land and interference by other HF signals and noise. Some sources of HF noise were distant (e.g. lightning or stray HF skywave signals) and others were local to the receiving antenna (e.g. powerline hum, ship's equipment). Mechanical and structural problems with the buoys and casing had to be dealt with before deployment into the ocean. A bad battery in buoy #649 caused low battery power and the inaccessibility of the batteries resulted in the problem not being corrected in a timely fashion. The software used to direct the buoy's operating parameters was indirect and resulted in many frustrating restarts. As a result, after a year of trying, including help directly from the designer, and improvements in all aspects of the buoys, antenna and receiver; data has not passed successfully through the entire system. The system has proven to be totally unreliable.

The data transmission and handling scheme is sophisticated. The care, maintenance, tuning, instructions, and handling, are all involved processes. Because of this, HF Loran-C buoy systems lack the reliability needed for an operational DMB system.

The design constraints imposed by the HF antenna requirements mean that the length of the buoy cannot be decreased. Therefore, it will always remain nine feet long. Consequently HF buoys are not small and cannot be made small. The cost of each prototype HF buoy was about $7000.

4.2 VHF Loran-C Buoys - Dobrocky-Seatech

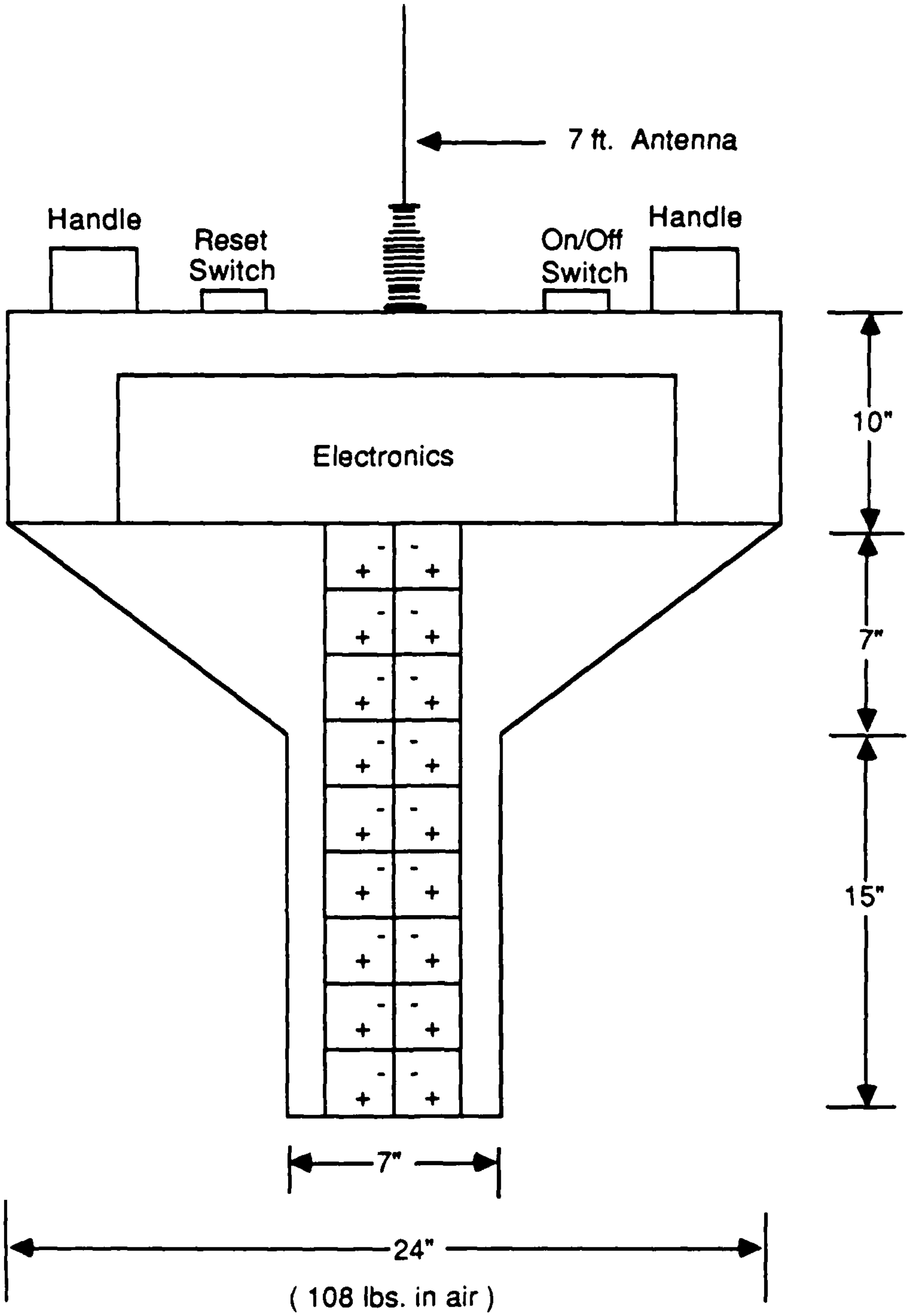
All five Dobrocky-Seatech VHF Loran-C buoys that have been tested have delivered useful data to the ship/shore based receivers. Data was consistently received from up to 25 nm with a shore/ship based receiver and 54-60 nm with a helicopter based receiver.

There have been problems with the VHF Loran-C buoys. However, as problems have been encountered with the buoys, Dobrocky-Seatech has made the necessary improvements to the buoys. The original EPROM instructions did not allow the on board storage option to be enabled. The EPROM was reprogrammed by Dobrocky-Seatech and now the use of on board memory is easy. The antenna mount has two problems. The ground strap within the coiled spring is susceptible to corrosion, which may cause transmission losses. Two buoys have suffered mechanical failures at the antenna mount bracket area. This causes the antenna to loosen which in turn prevents reception of the Loran-C signals. In addition, if the antenna switching and coupler attached to the bracket receive any sea water it would leak through the antenna mount hole. This entire area of the buoy is being redesigned. The 10 microsecond jumps due to locking on to the wrong zero crossing of the Loran-C signal was corrected by adjusting the 10 MHz timing crystal. The VHF buoys are now more reliable.

The basic design and operation is straight-forward. We have several options on the present model of buoy which was used for the tests and evaluations. These options (grid, interval, and repetition selection, and onboard memory) can be built into an operational buoy.

The present buoy model is much too large for operational use. However, Candel Industries Limited, Sidney, British Columbia, which has taken over the Loran-C buoy project from the now defunct Dobrocky-Seatech, is presently modifying the R&D Center buoys to fit in a 24 inch wide, 32 inch high "light bulb" shaped buoy hull, Figure 4-1. The weight in air is 108 pounds. A still smaller, air deployable model is in the early planning stage.

Buoys are approximately $8000.00 each and the receiver cost $1500. Buoy #16 survived a storm where the winds peaked at 70 knots and the waves reached 15-20 feet. This is the sort of ruggedness and reliability needed for Search and Rescue use.



Short Deployment Model

FIGURE 4-1 THE MODIFIED VERSION OF THE VHF LORAN-C BUOY BUILT BY CANDEL INDUSTRIES LIMITED.

CHAPTER 5

CONCLUSIONS AND FOLLOW-ON DEVELOPMENT

From the study conducted of Loran-C type buoys it is now considered feasible to proceed with the development of a small, lightweight, inexpensive replacement for the current RDF type DMB. The buoy can be designed for aircraft or shipboard use using largely off-the-shelf components. The two types of buoys tested differed only in the manner which they delivered data to the user/operator.

The HF Loran-C buoys have inherent design limitations which prevent them from meeting Coast Guard needs for a replacement for DMBs. They are unlikely to be able to meet those requirements. It is recommended that the Coast Guard no longer pursue the use of HF Loran-C buoys.

The VHF Loran-C buoys have great promise as eventual replacements for the presently used DMBs. Design changes are being made to the buoy to reduce size, weight and power consumption with testing and evaluation of the buoys continuing toward that end.

Several further tests are proposed for the buoys. The receiver should be tested aboard other Coast Guard aircraft, including the Falcon Jet and the C-130's. Plans to test the use of modems to send the data from the receiver to a remote computer using the GAADS system are being developed. Field tests in Hawaii, on Long Island Sound, and with CODAR off Miami are also planned. This will give more experience and provide input from operational SAR units.

The goal is a Loran-C buoy that is reliable, simple, small, inexpensive and part of the system used by Search Planners.

A reliable buoy must receive both the Loran-C signals and transmit the data to the receiver. The receiver must then output sensible data. Then each component of the system must work. The buoy must be able to sit for long periods on the shelf and then be deployed into the ocean. A reliable buoy must work in the ocean.

The buoy system must have simple operating instructions. Operation should only require the user to turn the buoy on, place it in the water, and collect the data. A scheme for processing the data should produce drift information immediately available to the users. Maintenance should consist of routine and simple battery checks.

A small buoy is necessary for easy deployment and storage. An aircraft deployable buoy must fit through the existing flare launch tubes (HC-130) or drop hatch (HU-25).

The cost of a buoy should be low when compared with other costs related to a search. A cost benefit study needs to be conducted to determine what buoy price would be considered low enough to make them completely or partially expendable. Some of the cost factors which should be considered are the savings of aircraft time in determining surface currents by this method versus the present DMBs, the savings of search unit time by having a better defined search area, the costs associated with recovery and savings associated with an overall improvement in search success. Costs considered should be full system, full-cycle costs.

A simple low-cost reliable system for delivering real-time current information and search datum to the search planner will be used, if the information gained results in less effort and greater success.

This report discusses the first half of the problem, getting data out of the buoys. Developing useful information for the search planner from the data will be coordinated with the program manager to assist in solving this second half of the search problem.

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